REMARKS

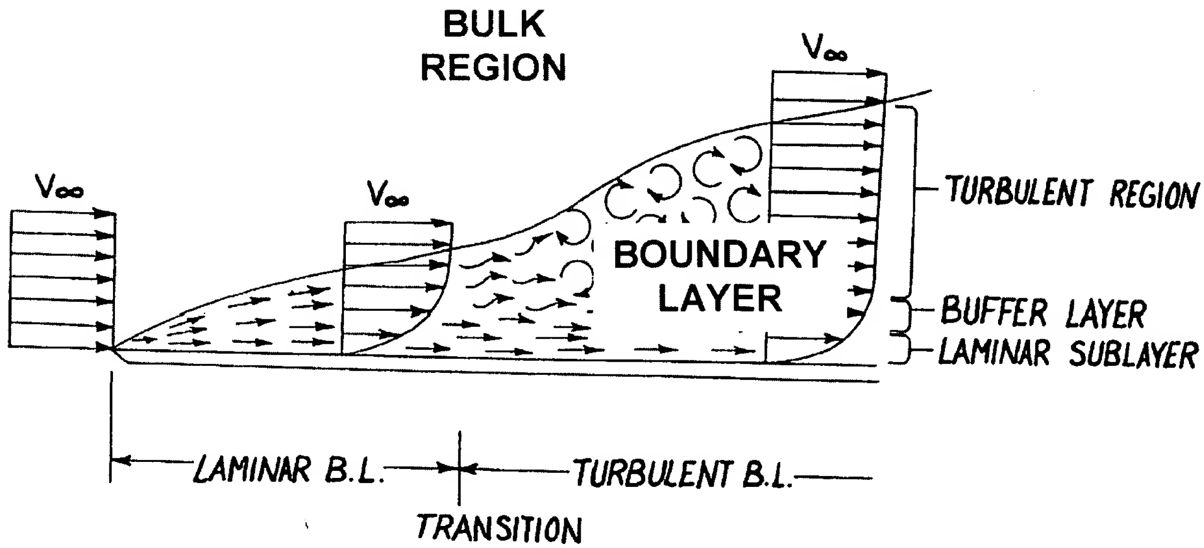
Claims 1-75 remain pending in the application. Claims 60-65 are allowed, Claims 1-59, 66-69, and 71-74 are rejected, and Claims 70 and 75 are objected to. The Examiner is respectfully requested to reconsider and withdraw the rejections in view of the amendments and remarks contained herein.

REJECTIONS UNDER 35 U.S.C. § 103

Claims 1-15, 21-32, 50-59, 66-69, and 71-74 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over JP '084 in view of JP '170. This rejection is respectfully traversed.

The claimed invention is directed to surface texturing that is distinct from the cited prior art references and that performs a cooling function in a way that has not been suggested or taught in the prior art. Referring to Figs. 13 and 14 of the present application, the general flow of a gas in the boundary layer along a surface defines a laminar region and a turbulent region. The boundary layer is initially laminar near the front or leading edge, and as the flow continues moving aft, the flow transitions to a turbulent flow. Within the turbulent region, three regions exist: a sublayer where the flow is generally smooth, a turbulent region where the flow is turbulent, and a buffer layer in between. The flow of gas below the solid line defining these regions is generally referred to as the boundary layer, and the region above the boundary layer is often referred to as the "bulk region" as shown immediately below.

FIG. 13



These general boundary layer flow principles are drawn from "Fundamentals of Heat and Mass Transfer," Second Ed., 1985. Specific excerpts from this textbook further detailing these flow principles are included herewith for the Examiner's reference.

Due to the relatively small texturing provided by the present invention, which is added to a surface within a preexisting gas passageway, (i.e., the texturing does not form the actual passageway as does the cited prior art), the flow **within the laminar boundary layer**, and more specifically near the front or leading edge of the flow, is turbulated. The texturing according to the claimed invention promotes turbulence within the laminar boundary layer while not changing the flow pattern in the bulk region above the boundary layer.

Due to the size and configuration of the prior art features that swirl or direct the flow of working gas, i.e. the grooves which actually create the passageway, these features function to affect the flow in the bulk region, **not** within the laminar boundary

layer. Although these features lend to increased turbulence, this increased turbulence is limited to the bulk region. The features, or grooves, of the prior art references do not function to turbulate the flow within the laminar boundary layer.

Accordingly, Applicants have amended the rejected claims to include the limitation of relatively small texturing to promote turbulence <u>within the laminar boundary layer while not changing the flow pattern in the bulk region</u>. Since neither JP '084 nor JP '170 disclose or teach the principles of turbulating flow within the laminar boundary layer, the amended claims cannot be obvious, and the Applicants respectfully request that the present claim rejections be withdrawn.

As previously submitted, JP '084 discloses grooves are provided on the outer face of the tip 2 and on the inner face of the cap 3 in order to provide a passageway, or a flow path, for the flow of secondary gas. Similarly, JP '170 discloses "grooves" that "<u>function as the flow path</u> for the working gas ..." and that "<u>create the gap as the flow path</u> for the working gas." Therefore, the grooves provided by the prior art references function to create the gas passageway through which a working gas flows and to increase the surface area for increased cooling. As a result, these grooves tend to increase turbulence in the bulk region, not the laminar boundary layer. These references do not disclose or teach turbulating a laminar boundary layer, or increasing the turbulence within a boundary layer, to enhance convective cooling.

Additionally, the grooves in JP '170 "function as fins to increase the heat radiation effect of the electrode ... and the surface area in contact with the working gas is also increased." Since the prior art features function in a different way than the

texturing according to the claimed invention, and thus do not satisfy the limitations of the amended claims, the rejected claims cannot be obvious.

Since neither of the cited references teach or disclose relatively small surface texturing to perform the function of increasing turbulence within the laminar boundary layer while not changing the flow pattern in the bulk region, the claimed invention cannot be obvious. Therefore, Applicants respectfully request that the present claim rejections be withdrawn.

Claims 16-20 and 45-49 stand rejected under 35 U.S.C. §103(a) as being unpatentable over JP '084 in view of JP '170 as applied to claims set forth above, and further in view of Luo et al '040. This rejection is respectfully traversed.

Claims 16-20 and 45-49 have also been amended to include the limitation of relatively small texturing to promote turbulence <u>within the laminar boundary layer while not changing the flow pattern in the bulk region</u>. Since JP '084, JP '170, and Luo et al '040 do not disclose or teach such a structure and function, the amended claims cannot obvious for at least the reasons stated above in connection with Claims 1-15, 21-32, 50-59, 66-69, and 71-74. Accordingly, Applicants respectfully request that these claim rejections also be withdrawn.

Claims 33-44 stand rejected under 35 U.S.C. §103(a) as being unpatentable over JP '084 in view of JP 170' and in further view of Stuart et al. The claims that include limitations directed to an electrode connection (34-36) depend from the amended independent claim 33 and distinguish over the prior art for at least the reasons stated above. Independent Claim 33 and dependent claims 37-44 which depend therefrom

distinguish over these cited references for at least the reasons stated above, namely, that the cited prior art does not disclose relatively small texturing to promote turbulence <u>within the laminar boundary layer while not changing the flow pattern in the bulk region</u>. Therefore, Applicants respectfully request that the present claim rejections be withdrawn.

Claims 70 and 75 are objected to as being dependent on a rejected base claim. Claim 70 depends from Independent Claim 66, and Claim 75 depends from Independent Claim 74. Claims 66 and 74 have been amended as described above and thus Claims 70 and 75 should now be in condition for allowance for at least the reasons stated above in connection with Claims 66 and 74. Therefore, Applicants respectfully request that these claim objections be withdrawn.

<u>CONCLUSION</u>

It is believed that all of the stated grounds of rejection have been properly traversed, accommodated, or rendered moot. Applicant therefore respectfully requests that the Examiner reconsider and withdraw all presently outstanding rejections. It is believed that a full and complete response has been made to the outstanding Office Action, and as such, the present application is in condition for allowance. Thus, prompt and favorable consideration of this amendment is respectfully requested. If the Examiner believes that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at (314) 726-7524.

Respectfully submitted,

Dated: 13 JUN 05

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FUNDAMENTALS OF HEAT AND MASS TRANSFER

SECOND EDITION

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David P. DeWitt

School of Mechanical Engineering
Purdue University

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$$\left.\frac{\partial p_A}{\partial y}\right|_{y=0} = \frac{(0-0.1)\ \text{atm}}{(0.0022-0)\ \text{m}} = -45.5\ \text{atm/m}$$

Hence

$$h_{m,x} = \frac{-0.288 \times 10^{-4}\ \text{m}^2/\text{s}\,(-45.5\ \text{atm/m})}{(0.1-0.02)\ \text{atm}} = 0.0164\ \text{m}^2/\text{s}$$

Comments:

From thermodynamic equilibrium at the liquid-vapor interface, the interfacial temperature was determined from Table A.6.

6.2.4 Significance of the Boundary Layers

In summary, the velocity boundary layer is of extent $\delta(x)$ and is characterized by the presence of velocity gradients and shear stresses. The thermal boundary layer is of extent $\delta_t(x)$ and is characterized by temperature gradients and heat transfer. Finally, the concentration boundary layer is of extent $\delta_c(x)$ and is characterized by concentration gradients and species transfer. For the engineer the principal manifestations of the three boundary layers are, respectively, *surface friction*, *convection heat transfer*, and *convection mass transfer*. The key boundary layer parameters are then the *friction coefficient* C_f, and the *heat* and *mass transfer convection coefficients* h and h_m, respectively.

For flow over any surface, there will always exist a velocity boundary layer, and hence surface friction. However, a thermal boundary layer, and hence convection heat transfer, exist only if the surface and freestream temperatures differ. Similarly, a concentration boundary layer and convection mass transfer exist only if the surface concentration of a species differs from its freestream concentration. Situations can arise in which all three boundary layers are present. In such cases, the boundary layers rarely grow at the same rate, and the values of δ, δ_t, and δ_c at a given x location are not the same.

6.3 LAMINAR AND TURBULENT FLOW

An essential first step in the treatment of any convection problem is to determine whether the boundary layer is *laminar* or *turbulent*. Surface friction and the convection transfer rates depend strongly on which of these conditions exists.

As shown in Figure 6.6, there are sharp differences between laminar and turbulent flow conditions. In the laminar boundary layer, fluid motion is highly ordered and it is possible to identify streamlines along which particles move. Fluid motion along a streamline is characterized by velocity components in both the x and y directions. Since the velocity component v is in the direction normal to the surface, it can contribute significantly to the transfer of momentum,

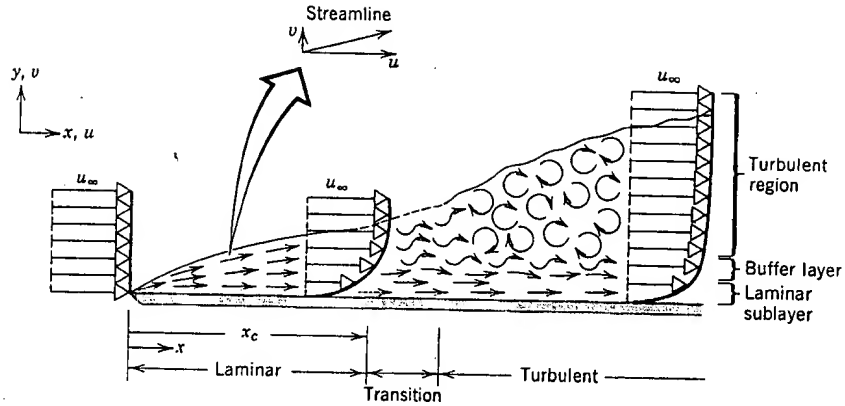

Figure 6.6 Velocity boundary layer development on a flat plate.

energy, or species through the boundary layer. Fluid motion normal to the surface is necessitated by boundary layer growth in the x direction.

In contrast, fluid motion in the turbulent boundary layer is highly irregular and is characterized by velocity fluctuations. These fluctuations enhance the transfer of momentum, energy, and species, and hence increase surface friction as well as convection transfer rates. Fluid mixing resulting from the fluctuations makes turbulent boundary layer thicknesses larger and boundary layer profiles (velocity, temperature, and concentration) flatter than in laminar flow.

The foregoing conditions are shown schematically in Figure 6.6 for velocity boundary layer development on a flat plate. The boundary layer is initially laminar, but at some distance from the leading edge, transition to turbulent flow begins to occur. Fluid fluctuations begin to develop in the *transition region*, and the boundary layer eventually becomes completely turbulent. The transition to turbulence is accompanied by significant increases in the boundary layer thicknesses, the wall shear stress, and the convection coefficients. These effects are illustrated in Figure 6.7 for the velocity boundary layer thickness δ and the local convection heat transfer coefficient h. In the turbulent boundary layer, three different regions may be delineated. We may speak of a *laminar sublayer* in which transport is dominated by diffusion and the velocity profile is nearly linear. There is an adjoining *buffer layer* in which diffusion and turbulent mixing are comparable, and there is a *turbulent zone* in which transport is dominated by turbulent mixing.

In calculating boundary layer behavior it is frequently reasonable to assume that transition begins at some location x_c. This location is determined by a dimensionless grouping of variables called the *Reynolds number*,

$$Re_x \equiv \frac{\rho u_\infty x}{\mu} \tag{6.23}$$

where the characteristic length x is the distance from the leading edge. The

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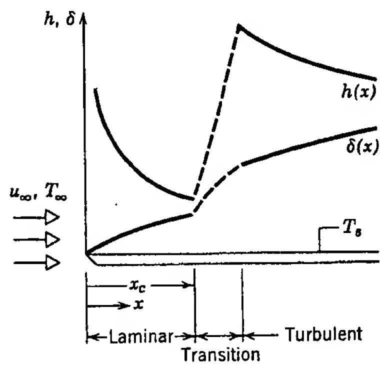

Figure 6.7 Variation of velocity boundary layer thickness δ and the local heat transfer coefficient h for flow over an isothermal flat plate.

critical Reynolds number is the value of Re_x for which transition begins, and for external flow it is known to vary from 10^5 to 3×10^6, depending on surface roughness, the turbulence level of the free stream and the nature of the pressure variation along the surface. A representative value of

$$Re_{x,c} = \frac{\rho u_\infty x_c}{\mu} = 5 \times 10^5 \tag{6.24}$$

is generally assumed for boundary layer calculations and, unless otherwise noted, is used for the calculations of this text.

6.4 THE CONVECTION TRANSFER EQUATIONS

We can improve our understanding of the physical effects that determine boundary layer behavior and further illustrate its relevance to convection transport by developing the equations that govern boundary layer conditions. Consider the simultaneous development of velocity, thermal, and concentration boundary layers over the surface of Figure 6.8. The fluid is considered to be a binary mixture of species A and B, and the species A concentration boundary layer originates from a difference between the freestream and surface concentrations ($C_{A,\infty} \neq C_{A,s}$). Selection of the relative thicknesses ($\delta_t > \delta_c > \delta$) is arbitrary, for the moment, and the factors that influence relative boundary layer development are discussed later in this chapter. To simplify the development we assume two-dimensional, steady flow conditions for which x is in the direction along the surface and y is normal to the surface. Extension of this development to three-dimensional flows may be readily made [1–3].

For each of the boundary layers we will identify the relevant physical effects and apply the appropriate conservation laws to control volumes of infinitesimal size. Although it is not essential to follow in detail the derivation of the conservation equations, you should attempt to develop an understanding of the underlying physical effects.